SYSTEMS AND METHODS FOR MONITORING PHYSICAL THERAPY OF THE KNEE AND OTHER JOINTS

CROSS-REFERENCE

[0001] This application is a continuation of PCT Application No. PCT/US2017/059286, filed Oct. 31, 2017, which claims the benefit of U.S. Provisional Application Nos. 62/455,986, filed Feb. 7, 2017, and 62/415,155, filed Oct. 31, 2016, which are incorporated herein by reference in their entirety.

BACKGROUND

[0002] Outcomes of joint surgeries (e.g., total hip arthroplasty, ACL repair, rotator cuff repair, etc.) vary and results depend on patient compliance with prescribed physiotherapies. Non-compliance with the prescribed therapies may be attributed to: (i) uncertainty or lack of clarity about how much or how little to perform an exercise (i.e., how much should the joint flex or extend), (ii) lack of supervision or reminders to perform an exercise (e.g., ice and elevate joint every two hours), (iii) lack of feedback or information on the patients progress (e.g., the joint is moving 5° more this week compared to last week), and (iv) lack of visibility by the clinician of the patients progress (i.e., clinician may only see the patient 3 weeks post-surgery), among other things.

[0003] There are therefore needs for improved systems, devices, and methods to monitor and encourage patient compliance with prescribed physical therapies.

[0004] References of interest may include the following: U.S. Pat. Nos. 9,008,784 and 9,271,858; and, U.S. Publication Nos. 20150045700, 20160007909, 20160202755, 20160213924, 2016022015, 20160242646, 20160302721, and 20160310140.

SUMMARY

[0005] This patent application describes systems, devices, and methods for post-surgical joint range of motion measurement, activity monitoring, as well as monitoring compliance with post-operative extremity elevation and cooling recommendations.

[0006] An exemplary device may measure and monitor joint position, motion, activity, swelling, and temperature, among other parameters, providing feedback for both patients and medical practitioners to facilitate patient compliance and improved outcomes.

[0007] An exemplary system may comprise (i) sensor(s) to be attached to a joint of the patient, (ii) applications running on a computing device of the patient and medical practitioner, such as a personal computer, laptop computer, smart speaker, smart home hub, smartphone, tablet, or wearable computer, and (iii) a cloud-based backend system to connect to the applications.

[0008] In one aspect, disclosed herein are systems for monitoring a joint of a subject, the system comprising: a plurality of adherent sensors for adhering to skin adjacent the joint, each adherent sensor comprising an adherent surface, a mechanical sensing element for sensing one or more mechanical parameters of the joint, and a transmitter; a local computing device in communication with at least one adherent sensor of the plurality of adherent sensors to receive measurement data from the at least one adherent sensor; and a remote computing device in communication with the local computing device to receive the measurement data and provide analysis of the measurement data to the local computing device, the local computing device providing the analysis to the subject. In some embodiments, at least one adherent sensor of the plurality of adherent sensors comprises a replaceable enclosure and a sensor assembly removable from the enclosure, the replaceable enclosure comprising the adherent surface and the sensor assembly comprising the mechanical sensing element and the transmitter. In some embodiments, the sensor assembly further comprises a power source comprising one or more of a power supply, a battery, a capacitor, or an energy harvesting element. In some embodiments, the at least one adherent sensor of the plurality of adherent sensors comprises an activation element coupled to the power source and the at least one adherent sensor is activated by at least partially removing the activation element. In some embodiments, the at least one adherent sensor of the plurality of adherent sensors is configured to be worn by the subject for at least six to eight weeks and the replaceable enclosure is configured to be replaced after one to two weeks of use while the sensor assembly is continually used after replacement of the replaceable enclosure. In some embodiments, the mechanical sensing element comprises one or more of a strain sensor, a force sensor, a flex sensor, a pressure sensor, an accelerometer, a magnetometer, a gyroscope, a potentiometer, a barometer, a piezoelectric sensor, a pressurized tube sensor, a coiled conductor sensor, a magnetic sensor. In some embodiments, the mechanical sensing element is configured to measure one or more of an elevation of the adherent sensor, a pitch, roll, or yaw of the adherent sensor, an orientation of the adherent sensor relative to gravity, an orientation of the adherent sensor relative to a paired adherent sensor, an orientation of the adherent sensor relative to the joint, motion of the adherent sensor, motion of the joint, motion of tissue adjacent the joint, a deformation of the adherent sensor, stress on the adherent sensor, or strain on the adherent sensor. In some embodiments, the at least one adherent sensor of the plurality of adherent sensors further comprises one or more of a temperature sensor, a humidity sensor, an electrical impedance sensor, an acoustic impedance sensor, an electromyography (EMG) sensor, an oxygen sensor, a pH sensor, an optical sensor, an ultrasound sensor, a glucose sensor, or a biomarker sensor. In some embodiments, the measurement data comprises one or more of an elevation of the at least one adherent sensor, a pitch, roll, or yaw of the at least one adherent sensor, an elevation of the at least one adherent sensor relative to a paired adherent sensor of the plurality of adherent sensors, a temperature of the skin adjacent the joint, motion of the at least one adherent sensor, motion of the at least one adherent sensor relative to the paired adherent sensor, an orientation of the at least one adherent sensor, an orientation of the at least one adherent sensor relative to the paired adherent sensor, an orientation of the at least one adherent sensor relative to the joint, a stretching or shrinkage of the at least one adherent sensor, an oxygenation of tissue adjacent the joint, a humidity of the tissue adjacent the joint, a muscle activity of the joint, an electrical impedance of the tissue adjacent the joint, an acoustic impedance of the tissue adjacent the joint, or one or more biomarkers. In some embodiments, the local computing device comprises one or more of a personal computer, a laptop computer, a tablet computer, a smart phone, a smart TV, a gaming console, a digital media player, a smart